AD 726919

TECHNICAL REPORT
71-50-CE

RELATIONSHIP OF TENSILE AND TEAR STRENGTHS OF FABRICS TO COMPONENT YARN PROPERTIES

by

Vasant K. Devarakonda

and

Clarence J. Pope

August 1970

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Clothing & Personal Life Support Equipment
Laboratory
TS-175

54

Approved for public release;
distribution unlimited

AD________________

TECHNICAL REPORT
71-50-CE

RELATIONSHIP OF TENSILE AND TEAR STRENGTHS OF FABRICS TO COMPONENT YARN PROPERTIES

by

Vasant K. Devarakonda

and

Clarence J. Pope

Series: TS-1[illegible]

August 1970

Clothing and Personal Life Support Equipment Laboratory
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

BLANK PAGES IN THIS DOCUMENT WERE NOT FILMED

Approved for public release; distribution unlimited.

Citation of trade names in this report does not constitute an official indorsement or approval of the use of such items.

Destroy this report when no longer needed. Do not return it to the originator.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This investigation was conducted on six selected fabrics to determine the relationship of breaking load, elongation and tear strength of fabrics to the properties of the component yarns. A system for expressing fabric properties as ratios of the contributing yarn properties was developed. Two factors termed cloth assistance factor (CAF) and cloth elongation factor (CEF) were used to characterize the effect of thread crossings in the fabric structure. These two factors show a linear relationship. It was concluded that the excess of fabric strength and elongation over that of yarn strength, elongation and crimp was due to the crossing threads effectively reducing the lengths of yarn elements in the test specimen thus localizing the rupture mechanism.

Fabric tear strength and yarn strength were related through a third factor called tear efficiency factor (TEF). This factor defines the relationship between warp and filling tear strengths of the fabric in terms of the yarn strengths and threads per inch.

RELATIONSHIP OF TENSILE AND TEAR STRENGTHS OF FABRICS TO COMPONENT YARN PROPERTIES

1. Introduction

The functional performance of a woven fabric can be broken down into measurable engineering parameters of the fiber, yarn and fabric. This approach permits the prediction of the end item properties by first considering the fiber and then the yarn and translating these basic elements through weaving and finishing techniques into the ultimate fabric structure. In view of this, it is apparent that without adequate knowledge of the relationships between fiber, yarn and fabric properties, the prediction or design of fabric structures having specific performance capabilities in the finished product is indeed difficult.

This study was designed to explore the simplest forms of relationships that exist between fabric behavior under tensile and tear types of stresses and the properties of the component yarn elements in the fabric. Tensile and tear stresses were chosen because these are the strength characteristics most commonly used in routine quality assessment.

Taylor (1) in his study of tensile and tearing strengths of cotton cloths, states that the usefulness of the test for cloth strength is one of assessment of quality and not one of assessment of serviceability. Nevertheless, when a demand for a minimum strength is added to the cloth specification, the manufacturer is restricted to a minimum quality fiber and yarn and to a range of twist factors. Therefore, a fall in strength may yield a valuable warning of a change in the quality of raw material or yarn or of a deterioration in the control of finishing processes.

Yarn breaking strength, breaking elongation and crimp are the primary factors influencing a great many fabric properties. The integral yarn strength is a major contributing factor to both tensile strength and tear strength of fabrics. Crimp in yarns and the ultimate elongation are once again major contributing factors to the ultimate fabric elongation.

The ratio of fabric breaking load per single yarn to yarn breaking load was discussed by Taylor (1) for cotton cloths. This ratio is known as the "cloth strength factor" or "cloth assistance factor" (CAF) and is defined as:

$$\mathrm{CAF} = \frac{F}{nf}$$

Where: F = Fabric breaking strength as determined by strip method.

n = Number of longitudinal threads in the fabric strip.

f = Breaking strength of the yarn.

Taylor (1) states that the presence of crossing threads in the fabric test specimen has three effects: (1) they tend to localize the rupture thus modifying the simple theory of the strength of a band of threads; (2) they cause crimping of the longitudinal threads so that they do not lie continuously in the direction of stress; and (3) they increase the binding of the fibers in the individual yarns thereby increasing strength.

While tensile strength of a fabric is useful as a quality characteristic, tear strength, in contrast, is more directly involved in the assessment of serviceability. The reason for this is that in order to break a fabric by a tensile stress, the applied force must be capable of breaking many threads simultaneously, whereas to tear a cloth, the threads are broken singly. It is therefore a frequent mode of fabric failure. The fabric failure in tear also involves a complex mechanism of stress application. Therefore, it is important to understand the mechanism of fabric failure in tear. The most frequently used description of the mechanism of fabric failure in the tongue tear test (2) is described below.

On application of force to the fabric by the testing machine, the yarns held longitudinally between the jaws stretch and lose crimp and then start slipping across the transverse yarns, forming a del-shaped (∇) opening in which there are no longitudinal yarns (see Figure 1). As the load is increased the longitudinal yarns continue to slip and crowd together, increasing the size of the del and forming a large number of frictional points of contact in a small area of fabric. As the number of these contact points builds up, it becomes more and more difficult for slippage to occur and the load is progressively transferred to the transverse yarns, which are held in tension in the del-shaped "pseudo-jaw". As the load builds up further, some of the transverse yarns fail and again yarns slip by each other to form a new "pseudo jaw", and so on, in a cycle, until the failure extends over the length tested. Thus, according to the hypothesis, failure of the yarns in a tongue-tear test occurs in tension, while the yarns are at an angle to the line of action of the jaws.

Schiefer et al (3) studied the effect of weave on the tear resistance of cotton fabrics. The factors which contribute to the tear resistance of a fabric are the strength of the yarns normal to the direction of tear and the freedom of movement of these yarns in the direction of tear. The movement of the yarns in the direction of tear helps to distribute the applied stress over several adjacent yarns. The greater the freedom of movement, the greater will be the number of adjacent yarns which will carry the applied stress and therefore the greater the tearing resistance.

In the process of manufacturing a finished cloth, the component yarns are subjected to various stresses and the physical properties of yarns

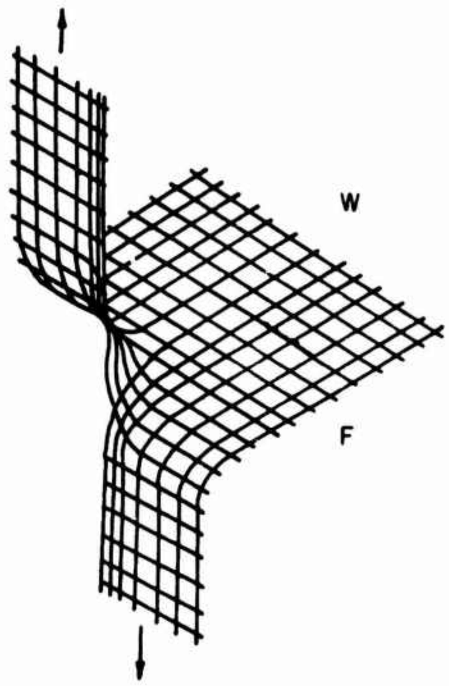


Figure I. FABRIC SPECIMEN UNDER TEAR

removed from the finished fabric may be related to, but not be the same as, the properties of yarn before fabrication. This study is concerned with the relationships between yarn and fabric properties and the properties of the yarns removed from the finished fabric.

2. Experimental Procedures

Six fabrics were used in this investigation. Five of these fabrics were all wool twill fabrics and one was a wool/polyester blend plain weave fabric. All fabrics were subjected to constructional analysis and the results are shown in Table I.

a. Yarn Tests

The yarns in warp and filling directions of the fabrics were investigated for breaking load and elongation, crimp and linear density. All four factors were determined using a constant rate of elongation tester (Instron) in accordance with ASTM Method D-1910. Ten-inch gage marks were made on the fabric in both warp and filling directions. The yarns from the fabric were then removed and mounted on the jaws of the tester set to 10-inch gage length with the length marks at the nips of the jaws. The crosshead speed was set to five inches per minute. Thirty warp and filling yarns from each fabric were tested. At the end of each test the yarn was cut at the nip of the jaws and held for further evaluation. After the completion of thirty tests for each direction, the combined yarns

TABLE I - DESCRIPTION OF FABRICS USED

Sample Code	Fiber Content (%)	Weave	Weight (oz/yd^2)	Texture (Ends x Picks)	Thickness (Mils)
1	Wool 100	Twill (Serge)	10.3	68 x 61	27.0
2	Wool 100	Twill (Serge)	11.4	69 x 55	29.4
3	Wool 100	Twill (Gabardine)	9.5	102 x 61	26.4
4	Wool 100	Twill (Elastique)	10.5	137 x 97	31.8
5	Wool 100	Twill (Lining)	5.3	53 x 47	21.8
6	Polyester 65 Wool 35	Plain	6.1	55 x 43	15.0

were weighed as a unit. The breaking load, break elongation and crimp values were determined from the Instron Tester chart. Using the value obtained for amount of crimp, the straightened length of the yarn was calculated for use in the determination of the linear density of the yarns.

b. Tensile Load and Elongation Test

The determination of the fabric breaking load and elongation in warp and filling directions was done on an Instron tester. The ravelled strip method used was in accordance with ASTM Method D-1682. Five specimens in each of warp and filling directions were prepared by ravelling down to 1 inch width. The Instron tester was set to 3 inches gage length, 1 inch per minute crosshead speed and 5 inches per minute chart speed. Breaking load and elongation were read directly from the chart.

c. Tear Strength (Single Rip)

The tear strength of the fabric in both warp and filling directions was determined in accordance with ASTM Method D-2261. The method specifies the use of a constant rate of elongation. Five specimens in each of warp and filling directions were tested on the Instron in combination with an integrator. The crosshead spead was 2 inches per minute and the chart speed was 5 inches per minute in all the tests. Although the integrator reading was used in calculating the tear strength, the Instron tester chart was also run during the tests for further analyses.

3. Results and Discussion

In the introduction it was stated that the object of this study was to explore the simplest forms of relationships that exist between yarn and fabric properties. Before proceeding to the correlation, the specific determined data for yarns are shown in Tables II and III.

TABLE II - WARP YARN PROPERTIES

Sample Code	Yarn Denier	Crimp (%)	Breaking Load (gms)	Elongation (%)
1	532.3	8.48	351.5	15.26
2	618.3	15.12	449.0	13.28
3	392.6	19.82	271.0	14.74
4	316.2	15.37	204.5	12.35
5	378.7	8.60	273.8	20.84
6	453.2	6.60	945.8	33.90

TABLE III - FILLING YARN PROPERTIES

Sample Code	Yarn Denier	Crimp (%)	Breaking Load (gms)	Elongation (%)
1	550.9	11.37	347.5	14.70
2	643.8	11.70	449.0	14.04
3	377.2	6.68	261.0	14.89
4	317.5	5.12	195.5	11.81
5	365.0	8.10	262.8	19.36
6	437.7	8.88	905.0	32.51

Similarly, the data on breaking load and elongation of the fabrics are shown in Table IV.

TABLE IV

BREAKING LOAD AND BREAKING ELONGATION OF FABRICS

Sample Code	Breaking Load (lbs) Warp	Breaking Load (lbs) Filling	Breaking Elongation (%) Warp	Breaking Elongation (%) Filling
1	62.4	56.0	39.0	42.3
2	76.6	61.0	42.3	40.0
3	70.8	41.4	61.9	34.3
4	75.6	46.4	52.0	21.7
5	33.0	28.4	35.9	30.8
6	118.8	87.8	54.5	51.7

The data on fabric tear strength are shown in Tables V and VI. The average tear strength shown in these tables was calculated from the integrator value and the load at first break was taken from the chart. The load at first break represents the load required to stretch the fabric to the breaking point. In other words, at this load, the size of the del (see Figure 1) at the point of tear is at its maximum. This load is always higher than the average tear strength as shown in Tables V and VI. The reason is that up to this load; crimp removal and yarn sliding takes place, but once the first break occurs the load is instantaneously transferred to the successive yarns. Therefore, the progress of the tear does not start until after this load is reached. The load to the first break is defined in this study as the "initial tear strength." In the later analysis of this initial tear strength it will be shown that it bears a similar relationship to fabric constructional parameters as does the average tear strength. As the average tear strength is obtained from the integrator reading, it must be understood that the average does not include the initial tear strength value. This is due to the fact

that in accordance with the method the integrator is not started until after the fabric starts to tear.

TABLE V - FABRIC TEAR STRENGTH (WARP)

Sample Code	Average Tear Strength (lbs) T_a	Load at First Break (lbs) T_i	$\frac{T_i}{T_a}$
1	3.72	5.18	1.39
2	5.25	7.46	1.42
3	3.98	5.54	1.39
4	4.63	6.60	1.43
5	5.45	9.84	1.81
6	9.16	11.84	1.29

TABLE VI - FABRIC TEAR STRENGTH (FILLING)

Sample Code	Average Tear Strength (lbs) T_a	Load at First Break (lbs) T_i	$\frac{T_i}{T_a}$
1	3.72	4.98	1.34
2	4.13	6.26	1.52
3	2.48	3.24	1.31
4	3.55	4.44	1.25
5	5.23	8.80	1.68
6	7.53	9.20	1.22

a. Relationship Between Fabric Breaking Load and Yarn Breaking Load

The cloth assistance factor (CAF) defined in the introduction of this report shows the effect of the presence of crossing threads in the test specimen and is useful in the comparison of fabrics with different constructions. Taylor (1) states that the strength of yarns is determined by the weakest place in the specimen. However, if the specimen length is very short, the variation of strength along the length is considerably smaller. The presence of crossing threads in the test specimen effectively shortens the yarn lengths under stress thus increasing the cloth strength.

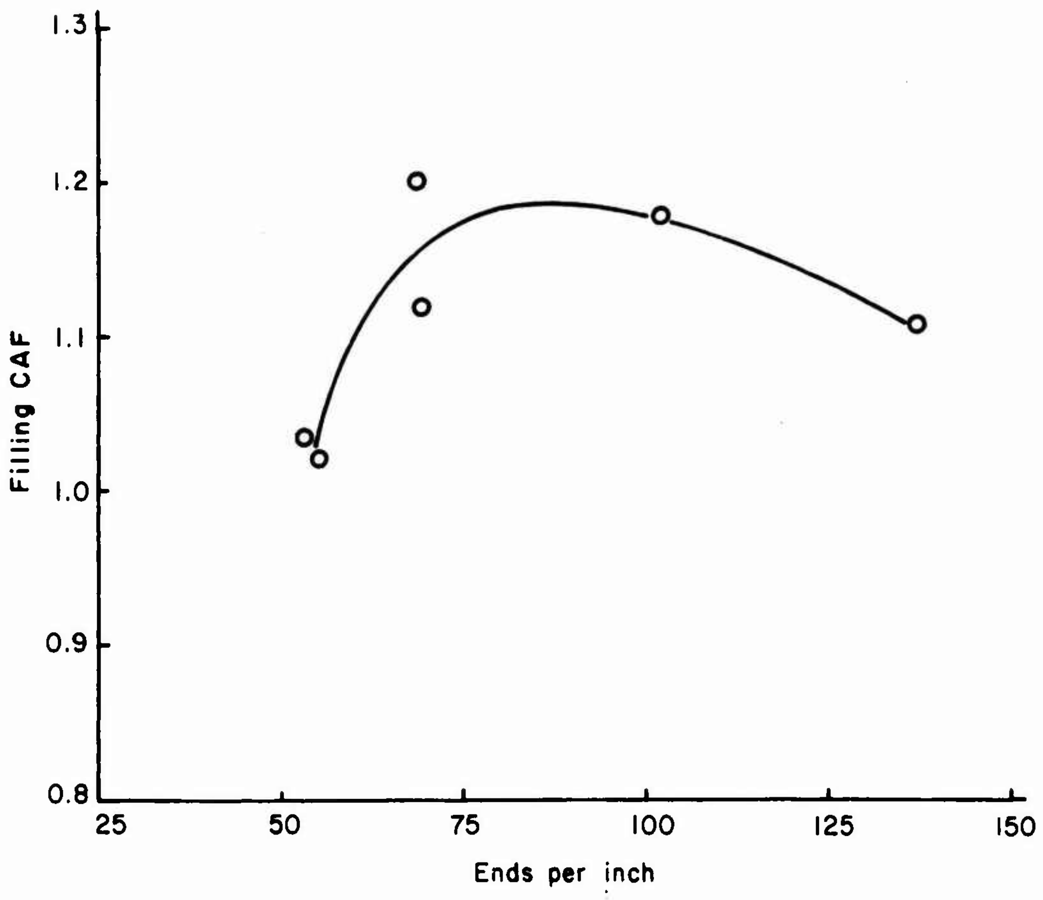


Figure 2. EFFECT OF INCREASE IN ENDS PER INCH ON THE FILLING CLOTH ASSISTANCE FACTOR

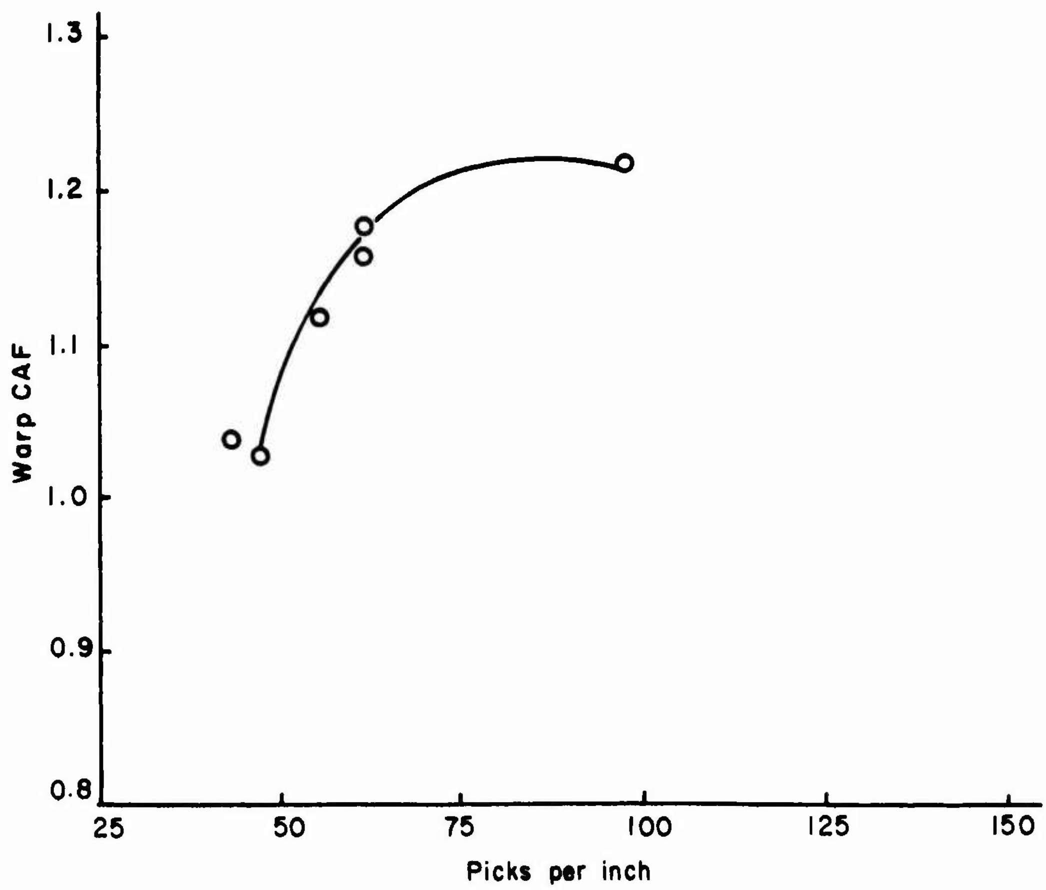


Figure 3. EFFECT OF INCREASE IN PICKS PER INCH ON THE WARP CLOTH ASSISTANCE FACTOR

To study this effect the cloth assistance factors in warp and filling were plotted against picks per inch and ends per inch, respectively. Figures 2 and 3 show this relationship. It is evident that the cloth assistance factor initially increases as the number of threads per inch increases in the direction opposite to the direction of stress. However, after reaching a limit, further increase in threads per inch results in reduction of the cloth assistance factor. The optimum number of threads per inch for the fabrics tested was approximately 90. Taylor (1) showed that for cotton fabrics this optimum is approximately 60 threads per inch.

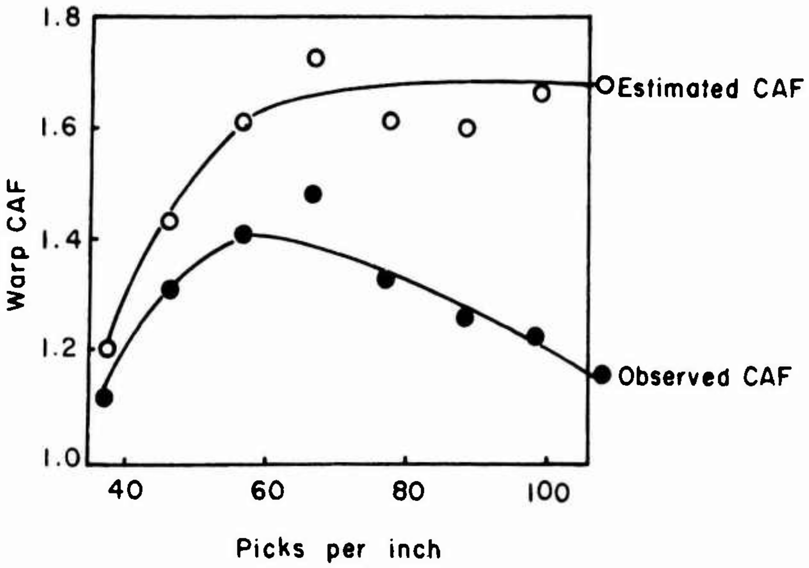


Figure 4. RELATIONSHIP BETWEEN CROSSING THREADS PER INCH AND CLOTH ASSISTANCE FACTOR - Taylor (1)

Taylor (1) suggests that the observed reduction in CAF beyond the optimum point is due primarily to several possible effects of yarn crimp. Based on experimental data, he showed through a plot of CAF vs. crimp (%) that a negative linear relationship exists for plied yarns with a loss ratio of one to one. Based on these data he applied a correction factor to the observed points in Figure 4, and obtained the estimated theoretical curve. He further reasoned that the weakening effects of increasing crimp or picks per inch do not exert their influence on single spun yarns such as those used in this study until a significant increase in CAF is obtained due to localization theory.

It is felt by the authors that the observed reduction in CAF is caused by either of the following two effects or a combination of both:

(1) According to the localization theory the crossing threads in the test specimen reduce the effective length of yarn elements in the

test specimen. Therefore, the length of the individual yarn elements depends on the distance between two consecutive crossing threads. If the fibers in the yarn are all held at the cross-over points and load is applied, the first break will occur in the shortest length fiber held between these two points. The differential lengths of fiber elements result in reduction in the strength of yarn elements which in turn causes the reduction in CAF. This effect becomes pronounced when the crossing threads get closer thus causing the reduction in CAF. The mechanism described so far assumes random orientation of fibers in the yarns and applies to spun yarns.

(2) Non-uniform stressing of the fibers in the yarns at the cross-over points could cause reduction in the strength of the yarn elements. At the cross-over point the fibers on the convex side of the crimp are subjected to smaller stresses than those on the inside of the curve. This effect becomes pronounced as the crossing threads get closer thus reducing CAF. This mechanism assumes that the fibers in yarns are well oriented and is applicable to filament yarns.

b. <u>Relationship Between Fabric Breaking Elongation, Yarn Breaking Elongation, and Crimp</u>

Feather and Anderson (4) state:

> "The extension at break of a fabric is determined by three main factors: 1) the mean breaking extension of the yarn, 2) an additional yarn extension due to the reduction by the cloth assistance factor of the effective length of the yarn elements and hence to an increase in breaking load and extension, 3) straightening of crimp."

It was therefore decided to establish a factor similar to the cloth assistance factor which would define the additional fabric extension resulting from the cloth assistance factor. The ratio of the fabric elongation to the sum of the yarn elongation and crimp would express such a factor conveniently. This factor is defined as the "cloth elongation factor" (CEF). These factors for warp and filling are shown in Tables VII and VIII, respectively.

It was found that there is a linear relationship between cloth assistance factor (CAF) and cloth elongation factor (CEF). Correlation analysis, shown in Appendix VIII, yielded correlation coefficients of 0.95 and 0.89 for warp and filling, respectively. The regression lines are shown in Figures 5 and 6. The equations for these relationships are as follows:

Warp: $Y = 3.16X - 2.00$

Filling: $Y = 2.59X - 1.48$;

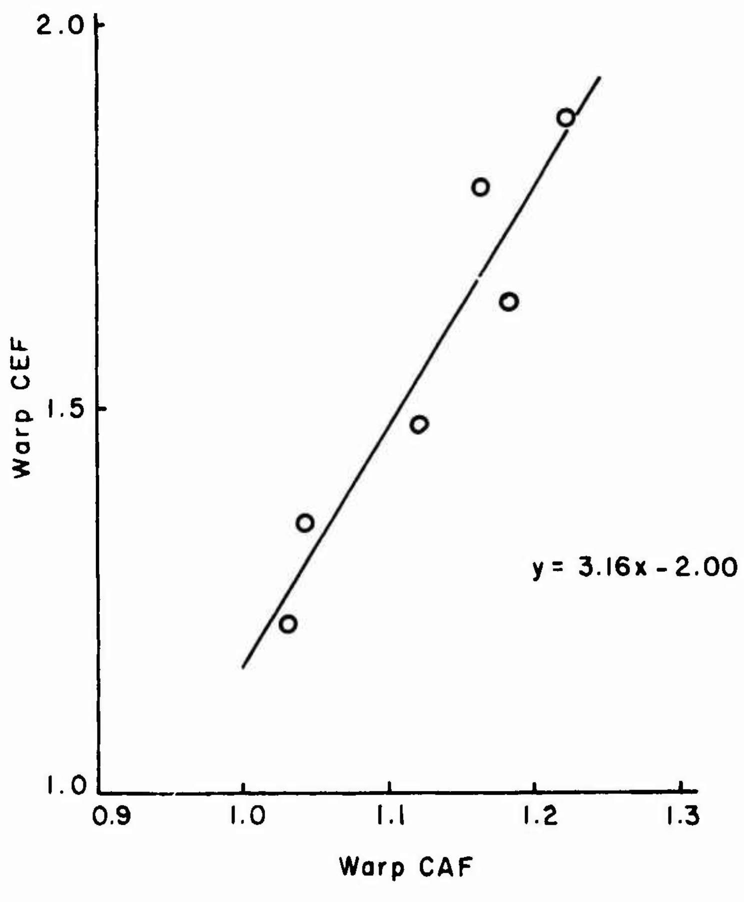


Figure 5. REGRESSION LINE SHOWING RELATIONSHIP BETWEEN CLOTH ASSISTANCE AND CLOTH ELONGATION FACTORS IN WARP

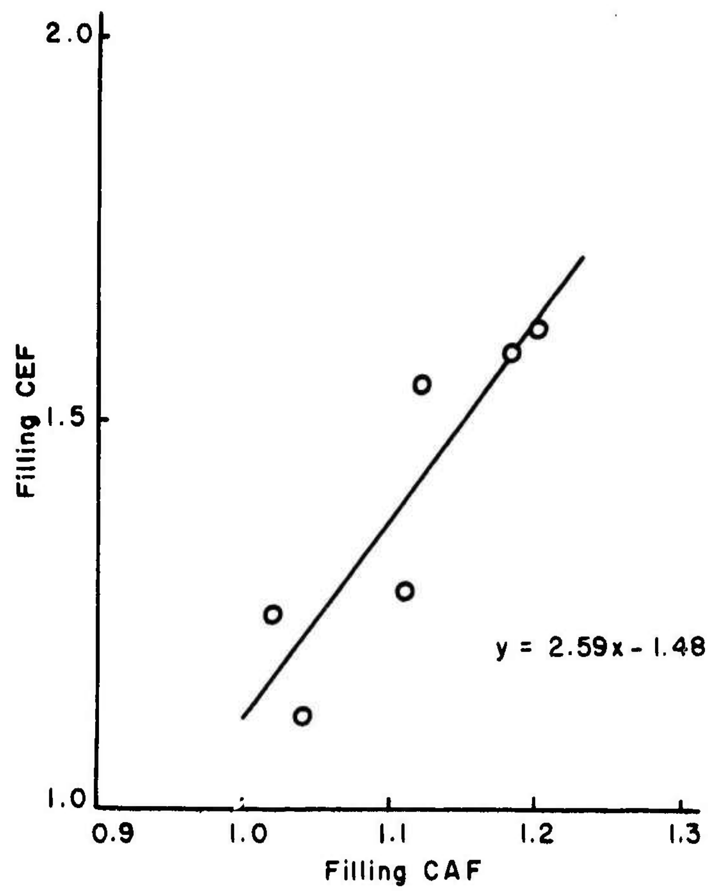


Figure 6. REGRESSION LINE SHOWING RELATIONSHIP BETWEEN CLOTH ASSISTANCE AND CLOTH ELONGATION FACTORS IN FILLING

Where: X = Cloth elongation factor,

Y = Cloth assistance factor.

TABLE VII - CLOTH ASSISTANCE AND CLOTH ELONGATION FACTORS IN WARP

Sample Code	Cloth Assistance Factor (CAF)	Cloth Elongation Factor (CEF)
1	1.18	1.64
2	1.12	1.49
3	1.16	1.79
4	1.22	1.88
5	1.03	1.22
6	1.04	1.35

TABLE VIII - CLOTH ASSISTANCE AND CLOTH ELONGATION FACTORS IN FILLING

Sample Code	Cloth Assistance Factor (CAF)	Cloth Elongation Factor (CEF)
1	1.20	1.62
2	1.12	1.55
3	1.18	1.59
4	1.11	1.28
5	1.04	1.12
6	1.02	1.25

c. Relationship Between Tear Strength and Yarn Strength

In the earlier discussion the importance of yarn strength to fabric tear strength was explained. Therefore, a factor incorporating these two variables was thought to be of considerable interest. Tear efficiency factor (TEF) is therefore defined as the ratio of the tear strength to the yarn strength.

Krook and Fox (2) state three ways by which the tear strength of a fabric can be increased: First, by reducing the thread count in the direction opposite to the direction of test (yarns W in Figure 1). Second, by using yarns with higher breaking load in the direction of test (yarns F in Figure 1). Third, by decreasing friction between yarns.

However, if it is assumed that the slipping force in warp and filling is the same, it is possible to relate the tear strength, yarn strength and thread count in warp and filling directions of the fabric. Such a factor could be of use in design modification for a specific end-use. Tear efficiency factors were calculated using both the initial tear strength and the average tear strength of the fabrics. These factors are shown in Table IX.

TABLE IX - TEAR EFFICIENCY FACTORS (TEF)

Sample Code	Warp Initial	Warp Average	Filling Initial	Filling Average
1	4.80	6.68	4.86	6.50
2	5.30	7.54	4.17	6.32
3	6.66	9.27	4.31	5.63
4	10.27	14.64	8.24	10.30
5	9.03	16.30	9.36	15.19
6	4.39	5.66	3.77	4.60

It was found that a linear relationship exists between the ratio of tear efficiency factors of warp and filling and the ratio of the ends per inch to picks per inch. These ratios are shown in Table X.

TABLE X - RATIOS OF ENDS TO PICKS PER INCH AND TEAR EFFICIENCY FACTORS

Sample Code	Ends per Inch / Picks per Inch	Initial: TEF Warp / TEF Filling	Average: TEF Warp / TEF Filling
1	1.11	1.03	0.99
2	1.25	1.19	1.27
3	1.67	1.65	1.54
4	1.41	1.42	1.25
5	1.13	1.07	0.97
6	1.28	1.23	1.16

A correlation coefficient of 0.99 resulted using initial tear strengths and a correlation coefficient of 0.95 resulted using average tear strengths. The regression lines are shown in Figures 7 and 8. The equations for these lines are as follows:

Using initial tear strength:

$$Y = 1.12X - 0.20$$

Using average tear strength:

$$Y = 0.96X - 0.06$$

Where: $Y = \frac{\text{Tear Efficiency Factor of Warp}}{\text{Tear Efficiency Factor of Filling}}$

$X = \frac{\text{Ends Per Inch}}{\text{Picks Per Inch}}$

In both equations Y is almost 1 when X is 1 and the intercept is very close to the origin; therefore, for practical purposes, these equations could be taken to represent 45° regression lines where Y = X. Using this approximation the equation could be written as follows:

$$\frac{TEF_w}{TEF_f} = \frac{n_1}{n_2}$$

Where: TEF_w = tear efficiency factor of warp

TEF_f = tear efficiency factor of filling

n_1 = number of ends per inch

n_2 = number of picks per inch

This equation can be further modified as:

$$TS_w = TS_f \times \frac{n_1}{n_2} \times \frac{YS_w}{YS_f}$$

Where: TS_w = tear strength of warp

TS_f = tear strength of filling

YS_w = yarn strength of warp

YS_f = yarn strength of filling

The last equation conveniently expresses the relationship of warp and filling tear strengths in terms of threads per inch and yarn strengths. It can be seen from this equation that the tear strength in warp and filling can be increased by reducing threads per inch in the opposite direction and by increasing the yarn strength in the direction of test.

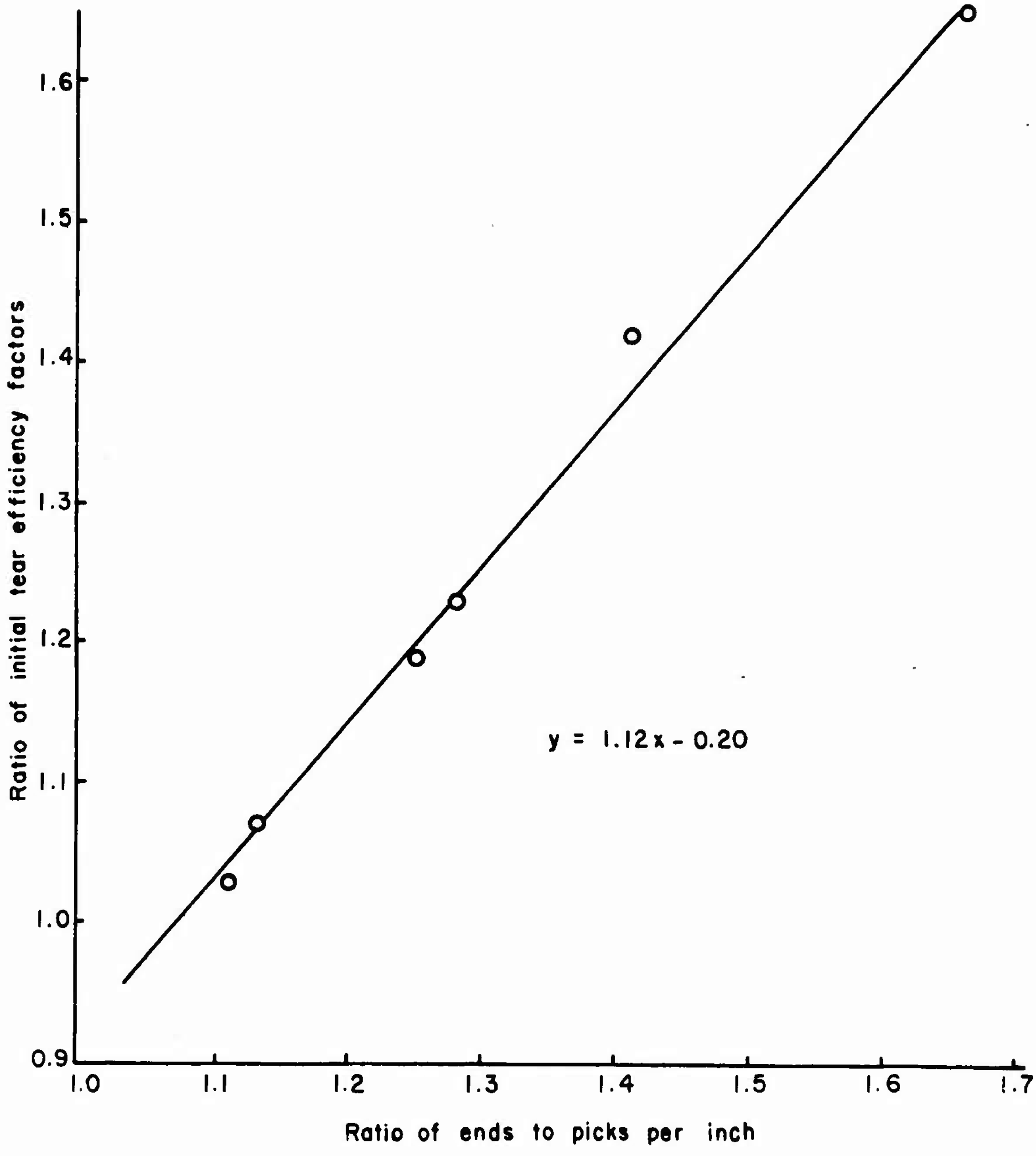


Figure 7. REGRESSION LINE RELATING THREADS PER INCH AND INITIAL TEAR EFFICIENCY FACTORS OF WARP AND FILLING

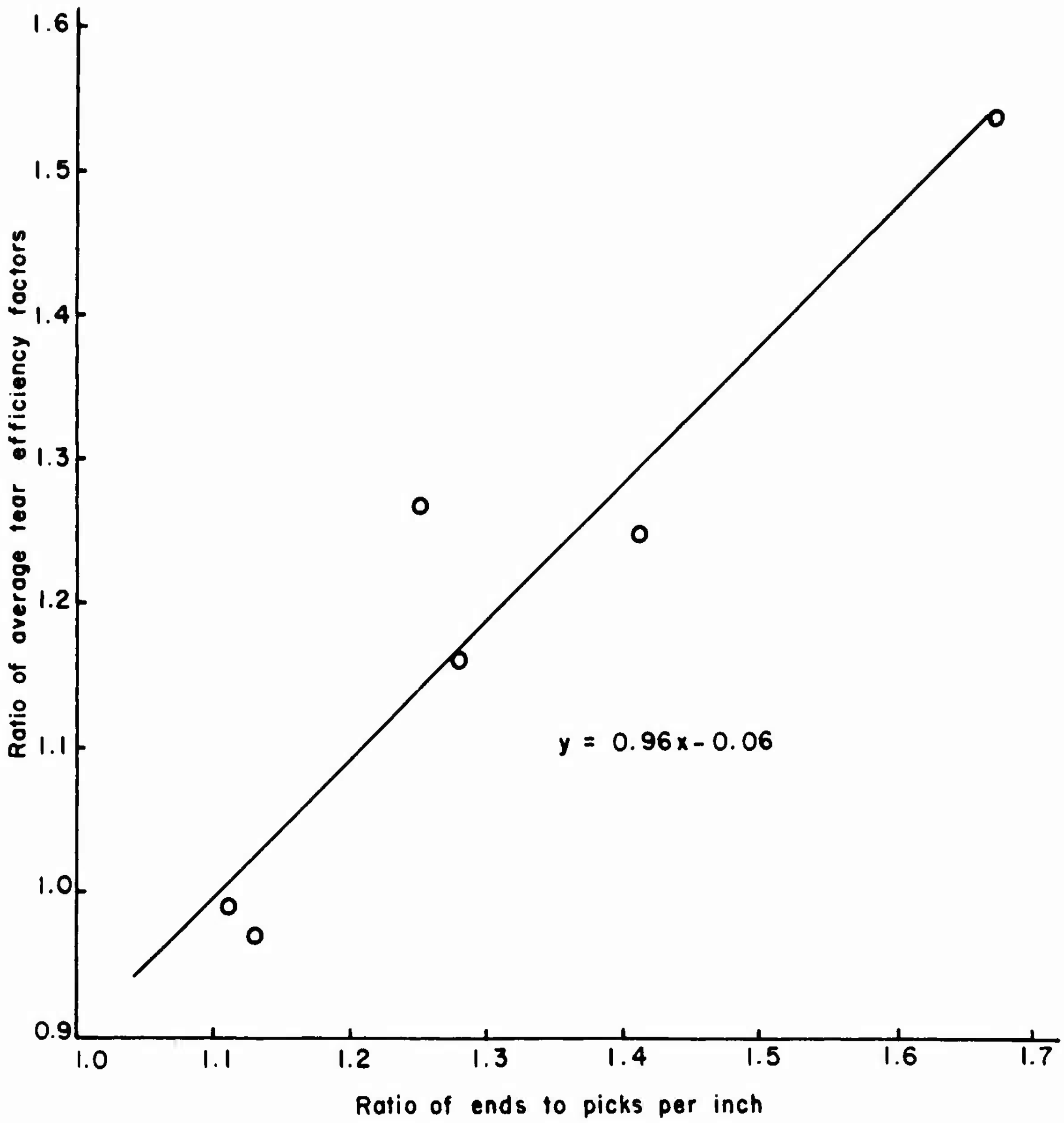


Figure 8. REGRESSION LINE RELATING THREADS PER INCH AND AVERAGE TEAR EFFICIENCY FACTORS OF WARP AND FILLING

In this discussion an attempt has been made to relate yarn properties to fabric properties. However, it must be emphasized that a certain amount of conflict exists as far as the tensile and tear strengths of fabrics are concerned. It was shown that the cloth assistance factor increases with the increase in crossing threads per inch, but an increase in threads per inch would reduce the tear strength. Therefore, the end-use requirement plays an important role in the choice of parameters in design modification of fabrics.

4. Conclusions

a. Cloth assistance factor (CAF) and cloth elongation factor (CEF) are useful measures in expressing the excess of fabric strength and elongation over that of the inherent yarn properties. These factors can be used in comparing fabrics of different construction and in the engineering design of fabrics.

b. The linearity of the relationship between cloth assistance factor and cloth elongation factor indicates that the localization of rupture theory is applicable to both strength and elongation of fabrics.

c. The reduction in the cloth assistance factor after an initial increase is due to either the differential fiber lengths between yarn cross overs or the non-uniform stressing of fibers at the yarn cross overs, or a combination of both.

d. There was a linear relationship between the ratio of ends and picks per inch and the ratio of tear efficiency factors in warp and filling. This relationship was found to be true for tear efficiency factors using average tear strength as well as those using initial tear strength.

e. The load required to initiate a tear in a fabric specimen is consistently higher than the average tear strength and must therefore be taken into consideration when examining the fabric behavior under a tearing stress.

f. The tearing strengths in warp and filling directions of a fabric are related and this relationship can be used in the design of fabrics for specific end-use requirements.

g. In general, the breaking strength of a fabric can be increased by increasing the number of threads per inch in the direction opposite to the direction of stress application up to an optimum value, beyond which any further increase would result in a reduction in the strength.

h. Similarly, the tearing strength in either warp or filling directions of a fabric can be increased either by reducing the number of threads per inch in the direction opposite to the direction of test or by increasing the yarn strength in the direction of test.

5. Recommendations

The importance of the knowledge of the inter-relationships between fabric properties and yarn and fiber properties is well recognized. Since this report is a limited study, the following recommendations are made for further work on the subject:

a. The relationships developed in this study are on fabrics made of spun yarns. Studies should be undertaken to extend these relationships to filament yarns.

b. Investigations should be made to study the applicability of Taylor's localization theory (1) to continuous filament yarns.

c. Attempts should be made to estimate the size of the del-shaped opening at the point of tear in tear strength testing and its relationship to the initial and average tear strengths of fabrics.

d. Relationship of fabric properties and yarn properties before the yarns are woven into the fabric should be investigated.

6. Bibliography

1. Taylor, H. M.
   Tensile and Tearing Strengths of Cotton Cloths.
   Journal of Tex. Inst., 50, T161 (1959)

2. Krook, C. M., and K. R. Fox
   Study of the Tongue-Tear Test.
   Textile Research J., 15, p. 389, (1945)

3. Schiefer, H. F., R. S. Cleveland, J. W. Porter, & J. Miller
   Effect of Weave on Properties of Cloth.
   National Bureau of Stds. J. Res., 11, p. 441, (1933)

4. Feather, Dorothy G., and S. L. Anderson
   Some Physical Properties of a Range of Worsted Fabrics.
   Journal of Tex. Inst., 58, T242, (1967)

APPENDIX I

TABLE 1 - FABRIC COUNT-ENDS PER INCH

Sample Code	Test Number 1	2	3	Average
1	68	68	69	68
2	69	70	69	69
3	102	101	103	102
4	138	136	137	137
5	54	52	52	53
6	54	56	54	55

TABLE 2 - FABRIC COUNT-PICKS PER INCH

Sample Code	Test Number 1	2	3	Average
1	60	60	62	61
2	55	55	54	55
3	60	60	62	61
4	96	98	96	97
5	46	48	47	47
6	44	42	42	43

APPENDIX II

FABRIC WEIGHT

Sample Code	Fabric Weight gms/20 in^2	Fabric Weight ozs/yd^2
1	4.5124	10.3
2	4.9745	11.4
3	4.1395	9.5
4	4.5919	10.5
5	2.2932	5.3
6	2.6819	6.1

CALCULATION OF FABRIC WEIGHT IN OUNCES PER SQUARE YARD

$$\frac{\text{ounces}}{yd^2} = \frac{\text{grams}}{20\ in^2} \times \frac{1296\ in^2}{yd^2} \times \frac{16\ \text{ounces}}{453.6\ \text{grams}}$$

$$\frac{\text{ounces}}{yd^2} = (\text{weight of } 20\ in^2 \text{ in grams})\ (2.29)$$

EXAMPLE: Sample 1

$$\frac{\text{ounces}}{yd^2} = (4.5124)\ (2.29)$$

$$= 10.3$$

APPENDIX III

FABRIC THICKNESS[a] IN INCHES

Sample Code	Test Number 1	2	3	4	5	Average
1	0.027	0.027	0.027	0.027	0.027	0.0270
2	0.029	0.029	0.030	0.030	0.029	0.0294
3	0.026	0.026	0.027	0.026	0.027	0.0264
4	0.032	0.032	0.032	0.031	0.032	0.0318
5	0.021	0.022	0.022	0.022	0.022	0.0218
6	0.015	0.015	0.015	0.015	0.015	0.0150

[a] Presser foot - 1 in^2; load - 16 ozs or 1 psi

APPENDIX IV

TABLE 1A - DATA ON YARN PROPERTIES

Sample 1 - Warp

Test Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	0.75	345	1.95
2	0.80	345	1.45
3	0.85	335	1.95
4	0.90	310	1.25
5	0.85	365	1.55
6	0.80	340	1.60
7	0.85	375	1.85
8	0.85	380	1.35
9	0.85	365	2.05
10	0.75	390	1.60
11	0.75	330	1.70
12	0.70	350	1.95
13	0.70	365	1.55
14	0.75	345	1.90
15	0.85	330	1.45
16	0.85	280	1.40
17	0.90	345	1.30
18	0.90	365	1.60
19	0.95	335	1.40
20	0.95	340	1.90
21	0.80	365	2.05
22	0.85	315	1.55
23	0.95	370	1.55
24	0.80	315	1.30
25	0.85	390	1.85
26	0.90	365	1.55
27	0.90	435	2.00
28	0.95	370	1.80
29	1.05	325	1.60
30	0.85	360	1.65
Totals	25.45	10,545	49.65

Total weight of the yarn specimens = 0.4900 grams

APPENDIX IV

TABLE 1B - DATA ON YARN PROPERTIES

Sample 1 - Filling

Test Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	1.10	330	1.60
2	1.20	335	1.75
3	1.05	440	2.20
4	1.10	365	1.30
5	1.20	315	1.20
6	1.00	325	1.75
7	1.25	340	1.45
8	1.25	385	1.75
9	1.25	335	1.75
10	1.20	380	1.55
11	1.10	360	2.00
12	1.15	325	1.55
13	1.05	350	1.85
14	1.10	330	1.40
15	1.10	345	1.85
16	1.10	385	1.80
17	1.20	365	1.65
18	1.15	335	1.25
19	1.15	340	1.85
20	1.15	320	1.45
21	1.15	310	1.25
22	1.10	300	1.80
23	1.15	315	1.30
24	1.10	285	1.10
25	1.10	390	1.85
26	1.15	415	1.95
27	1.05	370	1.80
28	1.20	340	1.85
29	1.10	335	1.65
30	1.15	360	1.60
Totals	34.10	10,425	49.10

Total weight of the yarn specimens = 0.5206 grams

APPENDIX IV

TABLE 2A - DATA ON YARN PROPERTIES

Sample 2 - Warp

Test Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	1.60	420	1.30
2	1.60	410	1.25
3	1.55	470	2.00
4	1.55	420	1.35
5	1.55	420	1.50
6	1.45	495	1.70
7	1.55	490	1.50
8	1.50	430	1.15
9	1.55	430	1.65
10	1.65	440	1.25
11	1.50	475	1.70
12	1.55	440	1.95
13	1.50	450	2.15
14	1.50	460	1.50
15	1.60	425	1.65
16	1.40	430	1.25
17	1.45	450	1.55
18	1.45	400	1.00
19	1.60	490	1.75
20	1.55	425	1.20
21	1.50	470	1.55
22	1.35	460	1.65
23	1.50	485	1.95
24	1.50	410	1.45
25	1.45	470	1.70
26	1.50	480	1.45
27	1.50	440	1.35
28	1.45	460	1.50
29	1.50	410	1.20
30	1.45	515	1.70
Totals	45.35	13,470	45.85

Total weight of the yarn specimens = 0.6040 grams

APPENDIX IV

TABLE 2B - DATA ON YARN PROPERTIES

Sample 2 - Filling

Test Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	1.15	410	1.45
2	1.20	365	1.15
3	1.15	385	1.35
4	1.35	475	1.40
5	1.10	470	1.60
6	1.15	475	2.10
7	1.20	460	1.85
8	1.30	415	1.40
9	1.20	420	1.50
10	1.20	430	1.55
11	1.10	450	1.40
12	1.10	490	1.85
13	1.15	400	1.65
14	1.05	450	1.50
15	1.10	460	1.60
16	1.05	465	1.60
17	1.20	490	1.70
18	1.15	455	1.50
19	1.25	480	1.65
20	1.20	460	1.70
21	1.05	470	1.70
22	1.20	495	1.60
23	1.15	420	1.60
24	1.05	390	1.15
25	1.25	420	1.35
26	1.25	440	1.50
27	1.25	460	1.40
28	1.25	500	1.50
29	1.20	455	2.00
30	1.10	515	1.75
Totals	35.10	13,470	47.05

Total weight of the yarn specimens = 0.6102 grams

APPENDIX IV

TABLE 3A - DATA ON YARN PROPERTIES

Sample 3 - Warp

Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	2.15	280	2.35
2	2.00	235	1.25
3	2.05	285	1.85
4	1.85	280	1.35
5	2.00	295	1.60
6	1.95	255	1.70
7	2.10	280	1.30
8	2.00	305	2.25
9	1.90	235	2.10
10	2.10	290	2.20
11	1.70	285	1.95
12	2.15	270	1.35
13	1.90	240	1.30
14	2.10	275	1.60
15	2.15	290	1.85
16	1.90	290	2.05
17	1.95	300	1.75
18	2.10	235	1.75
19	1.95	240	2.15
20	1.90	290	2.60
21	1.80	265	1.80
22	1.95	275	1.55
23	2.00	230	1.45
24	1.85	250	1.70
25	2.00	275	1.55
26	2.05	305	2.15
27	1.90	250	1.50
28	2.00	295	1.75
29	2.00	245	1.55
30	2.00	285	1.70
Totals	59.45	8,130	53.00

Total weight of the yarn specimens = 0.3992 grams

APPENDIX IV

TABLE 3B - DATA ON YARN PROPERTIES

Sample 3 - Filling

Test Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	0.90	250	1.30
2	0.70	290	1.85
3	0.80	295	1.55
4	0.70	240	1.15
5	0.65	225	1.20
6	0.85	285	1.55
7	0.65	235	1.25
8	0.65	255	2.15
9	0.65	270	1.80
10	0.70	275	1.40
11	0.70	295	1.80
12	0.70	240	1.40
13	0.65	315	1.95
14	0.65	240	1.40
15	0.65	250	1.40
16	0.60	255	1.50
17	0.70	245	1.45
18	0.65	295	1.85
19	0.65	265	1.40
20	0.60	270	1.85
21	0.65	230	1.45
22	0.70	265	2.20
23	0.65	260	1.50
24	0.60	235	1.55
25	0.55	270	1.80
26	0.55	220	1.35
27	0.60	250	1.50
28	0.60	305	2.15
29	0.70	245	1.05
30	0.65	260	1.90
Totals	20.05	7,830	47.65

Total weight of the yarn specimens = 0.3415

APPENDIX IV

TABLE 4A - DATA ON YARN PROPERTIES

Sample 4 - Warp

Test Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	1.50	170	1.05
2	1.45	215	1.45
3	1.60	175	1.40
4	1.40	190	1.50
5	1.50	190	1.40
6	1.55	195	1.50
7	1.50	250	1.75
8	1.50	165	1.30
9	1.55	225	1.70
10	1.45	230	1.85
11	1.60	185	1.40
12	1.60	220	1.35
13	1.65	225	1.15
14	1.55	195	1.60
15	1.75	205	1.35
16	1.50	205	1.45
17	1.45	190	1.40
18	1.60	160	1.15
19	1.60	210	1.40
20	1.70	230	1.35
21	1.65	245	1.20
22	1.45	205	1.50
23	1.50	245	1.50
24	1.50	225	1.50
25	1.60	180	1.30
26	1.45	225	1.70
27	1.45	210	1.35
28	1.45	175	1.30
29	1.60	195	1.35
30	1.45	200	1.55
Totals	46.10	6,135	42.75

Total weight of the yarn specimens = 0.3095 grams

APPENDIX IV

TABLE 4B - DATA ON YARN PROPERTIES

Sample 4 - Filling

Test Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	0.50	190	1.20
2	0.55	180	1.00
3	0.45	190	1.20
4	0.55	190	1.40
5	0.55	200	1.75
6	0.60	200	1.20
7	0.50	200	1.30
8	0.55	190	1.30
9	0.40	215	1.40
10	0.40	200	1.70
11	0.55	200	1.35
12	0.60	190	1.30
13	0.50	205	1.15
14	0.65	195	1.25
15	0.45	235	1.20
16	0.50	195	1.35
17	0.50	195	1.10
18	0.45	205	1.35
19	0.45	210	1.50
20	0.55	175	1.15
21	0.45	170	0.90
22	0.55	200	1.00
23	0.55	200	1.00
24	0.55	225	1.40
25	0.50	160	1.00
26	0.55	195	1.30
27	0.50	200	1.25
28	0.45	140	0.95
29	0.55	200	1.10
30	0.45	215	1.20
Totals	15.35	5,865	37.25

Total weight of the yarn specimens = 0.2832 grams

APPENDIX IV

TABLE 5A - DATA ON YARN PROPERTIES

Sample 5 - Warp

Test Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	0.90	235	2.40
2	0.85	265	2.20
3	0.90	280	2.65
4	0.90	270	2.00
5	0.85	325	3.05
6	0.85	245	2.05
7	0.90	300	2.85
8	0.85	255	2.05
9	0.90	330	2.20
10	0.80	255	1.90
11	0.85	265	2.50
12	0.75	275	1.30
13	0.85	285	1.65
14	0.95	275	3.20
15	0.85	275	2.90
16	0.85	305	2.25
17	0.80	245	1.45
18	0.90	275	2.35
19	0.85	245	1.60
20	0.85	295	1.75
21	0.80	280	2.75
22	0.90	310	2.40
23	0.80	295	2.10
24	0.85	260	2.20
25	0.90	285	2.50
26	0.85	270	2.55
27	0.90	230	1.50
28	0.90	270	2.50
29	0.85	240	2.75
30	0.85	275	2.35
Totals	25.80	8,215	67.90

Total weight of the yarn specimens = 0.3490 grams

APPENDIX IV

TABLE 5B - DATA ON YARN PROPERTIES

Sample 5 - **Filling**

Test Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	0.90	270	2.40
2	0.90	265	2.05
3	0.80	210	1.30
4	0.90	245	2.30
5	0.80	225	1.60
6	0.85	260	2.05
7	0.80	210	1.75
8	0.80	220	1.60
9	0.80	235	2.05
10	0.85	265	1.85
11	0.80	260	2.05
12	0.85	290	1.75
13	0.75	280	1.45
14	0.75	270	1.85
15	0.80	310	2.05
16	0.80	270	2.65
17	0.80	280	3.00
18	0.80	280	2.30
19	0.85	230	1.40
20	0.85	225	1.80
21	0.80	290	2.50
22	0.80	280	2.90
23	0.75	255	2.55
24	0.75	270	1.80
25	0.85	310	2.80
26	0.80	280	1.90
27	0.80	290	2.65
28	0.75	230	1.90
29	0.80	265	2.15
30	0.75	300	2.40
Totals	24.30	7,870	62.80

Total weight of the yarn specimens = 0.3348 grams

APPENDIX IV

TABLE 6A - DATA ON YARN PROPERTIES

Sample 6 - Warp

Test Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	0.60	1100	3.70
2	0.70	1050	3.60
3	0.90	925	3.50
4	0.70	975	3.40
5	0.70	875	3.70
6	0.85	975	3.50
7	0.70	900	3.60
8	0.60	1025	4.00
9	0.70	1050	3.70
10	0.70	600	3.00
11	0.70	850	3.50
12	0.70	875	3.30
13	0.50	1050	3.70
14	0.50	1125	3.90
15	0.60	1000	4.00
16	0.50	800	3.20
17	0.60	975	3.90
18	0.60	950	3.70
19	0.60	1000	3.80
20	0.80	950	3.50
21	0.60	875	3.50
22	0.60	900	3.60
23	0.80	950	3.60
24	0.70	900	3.40
25	0.60	900	3.90
26	0.60	1000	3.60
27	0.60	800	3.40
28	0.65	1075	3.80
29	0.60	975	3.80
30	0.70	950	3.60
Totals	19.80	28,375	108.40

Total weight of the yarn specimens = 0.4100 grams

APPENDIX IV

TABLE 6B - DATA ON YARN PROPERTIES

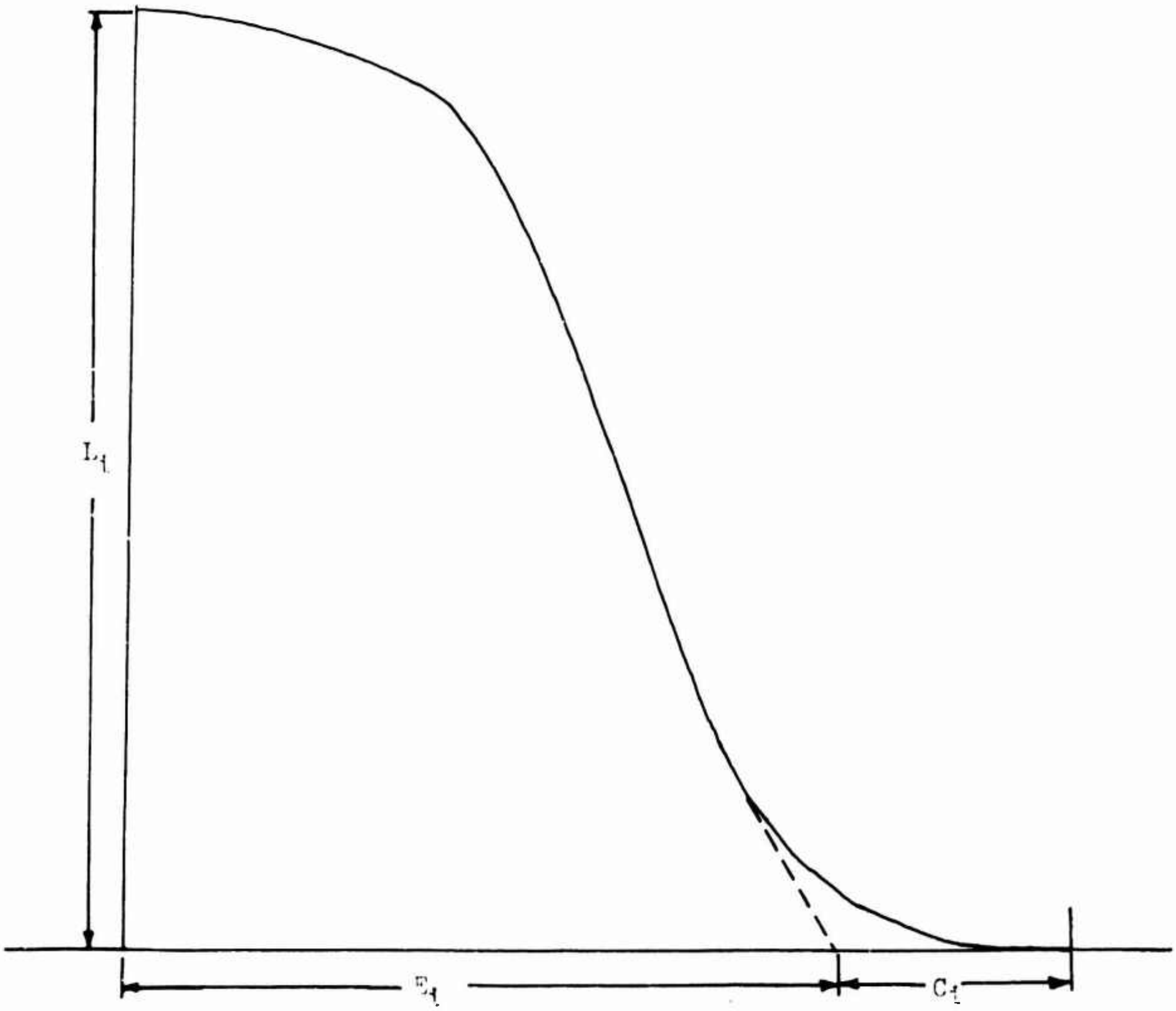
Sample 6 - Filling

Test Number	Crimp Extension (inches)	Breaking Load (grams)	Elongation (inches)
1	1.00	800	3.10
2	0.85	950	3.80
3	0.90	1025	3.60
4	0.90	750	2.70
5	0.80	1000	3.70
6	1.00	925	3.70
7	0.95	800	3.40
8	0.80	800	3.30
9	0.80	925	3.70
10	1.00	925	3.50
11	0.90	1000	3.80
12	0.90	900	3.70
13	0.90	825	3.30
14	0.80	925	3.70
15	0.80	925	3.50
16	0.70	900	3.60
17	0.90	800	3.50
18	1.00	925	3.50
19	0.70	925	3.60
20	1.10	875	3.30
21	0.95	900	3.50
22	0.75	875	3.90
23	1.00	850	3.50
24	0.90	950	3.50
25	0.85	950	3.70
26	1.10	1000	3.90
27	0.80	875	3.60
28	0.80	925	3.60
29	1.00	950	3.60
30	0.80	975	3.70
Totals	26.65	27,150	106.20

Total weight of the yarn specimens = 0.4044 grams

APPENDIX V

CALCULATION OF YARN PROPERTIES



INSTRON TESTER DIAGRAM FOR YARN TEST

Yarn Breaking Load: Sample 1 - Warp

$$\frac{\sum_{i=1}^{i=30} L_i}{30} = \frac{10,545}{30} = 351.5 \text{ gms.}$$

Crimp: Sample 1 - Warp

$$\frac{\sum_{i=1}^{i=30} C_i}{300} = \frac{25.45}{300} = 0.0848 \text{ or } 8.48\%$$

Yarn Breaking Elongation: Sample 1 - Warp

$$\frac{\sum_{i=1}^{i=30} E_i}{300 + \sum_{i=1}^{i=30} C_i} = \frac{49.65}{300 + 25.45} = 0.1526 \text{ or } 15.26\%$$

Yarn Denier: Sample 1 - Warp

Yarn Denier, $N = \frac{SW}{L}$ where,

$S = 4,464,500$ yds.

$$W = \frac{\text{Weight in grams}}{453.6} = \frac{0.4900}{453.6} \text{ lbs.}$$

$$L = \frac{300 + \sum_{i=1}^{i=30} C_i}{36} = \frac{300 + 25.45}{36} = 9.04 \text{ yds.}$$

$$\text{Yarn Denier, } N = \frac{4,464,500 \times 0.4900}{9.04 \times 453.6} = 532.3$$

APPENDIX VI

TABLE 1A - DATA ON FABRIC BREAKING LOAD IN WARP

Sample Code	Breaking Load (lbs) Test Number 1	2	3	4	5	Average
1	59.0	64.0	62.0	65.0	62.0	62.4
2	77.0	76.0	74.0	77.0	79.0	76.6
3	68.0	71.0	71.0	73.0	71.0	70.8
4	76.0	75.0	76.0	75.0	76.0	75.6
5	33.0	33.0	33.0	33.0	33.0	33.0
6	126.0	122.0	120.0	110.0	116.0	118.8

TABLE 1B - DATA ON FABRIC BREAKING LOAD IN FILLING

Sample Code	Breaking Load (lbs) Test Number 1	2	3	4	5	Average
1	55.0	57.0	57.0	56.0	55.0	56.0
2	62.0	60.0	60.0	61.0	62.0	61.0
3	42.0	41.0	41.0	42.0	41.0	41.4
4	46.0	45.0	49.0	46.0	46.0	46.4
5	29.0	28.0	28.0	29.0	28.0	28.4
6	85.0	91.0	86.0	88.0	89.0	87.8

APPENDIX VI (cont'd)

TABLE 2A - DATA ON FABRIC BREAKING ELONGATION IN WARP

Sample Code	Elongation on Chart (inches) Test Number 1	2	3	4	5	Average	Elongation (Inches)	Elongation (Percent)
1	5.0	6.4	6.0	6.0	5.9	5.86	1.17	39.0
2	6.2	5.9	6.1	6.7	6.8	6.34	1.27	42.3
3	8.0	8.9	9.2	10.2	10.1	9.28	1.86	61.9
4	8.5	7.4	7.6	7.6	7.9	7.80	1.56	52.0
5	5.1	4.9	5.5	5.1	6.3	5.38	1.08	35.9
6	8.4	8.2	8.3	7.7	8.3	8.18	1.64	54.5

TABLE 2B - DATA ON FABRIC BREAKING ELONGATION IN FILLING

Sample Code	Elongation on Chart (inches) Test Number 1	2	3	4	5	Average	Elongation (Inches)	Elongation (Percent)
1	6.6	6.5	6.0	6.4	6.3	6.36	1.27	42.3
2	5.9	6.1	5.6	6.0	6.4	6.00	1.20	40.0
3	5.4	5.1	5.0	4.7	5.6	5.16	1.03	34.3
4	3.1	3.4	3.3	3.2	3.3	3.26	0.65	21.7
5	4.4	4.7	4.8	4.6	4.6	4.62	0.93	30.8
6	7.8	7.8	7.8	7.7	7.7	7.76	1.55	51.7

APPENDIX VII

TABLE 1 - DATA ON TEAR STRENGTH OF FABRICS

Sample 1

Test Number	Integrator Reading Warp	Integrator Reading Filling	Tear Strength[a] (pounds) Warp	Tear Strength[a] (pounds) Filling	Load at First Break (pounds) Warp	Load at First Break (pounds) Filling
1	1900	1922	3.80	3.84	6.0	4.9
2	1839	1806	3.68	3.61	5.2	5.0
3	1821	1803	3.64	3.61	4.5	4.5
4	1874	1887	3.75	3.77	5.2	5.5
5	1874	1885	3.75	3.77	5.2	5.5
Averages -			3.72	3.72	5.18	4.98

TABLE 2 - DATA ON TEAR STRENGTH OF FABRICS

Sample 2

Test Number	Integrator Reading Warp	Integrator Reading Filling	Tear Strength[a] (pounds) Warp	Tear Strength[a] (pounds) Filling	Load at First Break (pounds) Warp	Load at First Break (pounds) Filling
1	2636	2093	5.27	4.1[illegible]	7.6	[illegible]
2	2308	2098	4.[illegible]	4.17	7.1	[illegible]
3	2621	2036	5.24	4.07	7.[illegible]	6.6
4	2761	2112	5.52	4.22	6.8	5.7
5	2713	2001	5.43	4.00	[illegible]	5.6
Averages -			5.25	4.13	7.4[illegible]	[illegible]

[a]Tear strength $= \frac{X \times L}{K}$ where, X = integrator reading
L = full scale load - 10 lbs.
K = integrator constant - 5000

APPENDIX VII

TABLE 3 - DATA ON TEAR STRENGTH OF FABRICS

Sample 3

Test Number	Integrator Reading Warp	Integrator Reading Filling	Tear Strength[a] (pounds) Warp	Tear Strength[a] (pounds) Filling	Load at First Break (pounds) Warp	Load at First Break (pounds) Filling
1	1872	1238	3.74	2.48	5.1	3.1
2	1942	1241	3.88	2.48	5.8	3.4
3	2069	1276	4.14	2.55	6.2	3.7
4	1832	1261	3.66	2.52	4.9	3.2
5	2228	1179	4.46	2.36	5.7	2.8
Averages -			3.98	2.48	5.54	3.24

TABLE 4 - DATA ON TEAR STRENGTH OF FABRICS

Sample 4

Test Number	Integrator Reading Warp	Integrator Reading Filling	Tear Strength[a] (pounds) Warp	Tear Strength[a] (pounds) Filling	Load at First Break (pounds) Warp	Load at First Break (pounds) Filling
1	2211	1973	4.42	3.59	6.8	4.3
2	2210	1722	4.42	3.44	7.1	4.2
3	2478	1768	4.96	3.54	6.1	4.3
4	2262	1805	4.52	3.61	7.0	5.1
5	2409	1779	4.82	3.56	6.0	4.3
Averages -			4.63	3.55	6.60	4.44

[a]Tear Strength = $\frac{X \times L}{K}$ where, X = integrator reading
L = full dcale load - 10 lbs
K = integrator constant - 5000

APPENDIX VII

TABLE 5 - DATA ON TEAR STRENGTH OF FABRICS

Sample 5

Test Number	Integrator Reading		Tear Strength[a] (pounds)		Load at First Break (pounds)	
	Warp	Filling	Warp	Filling	Warp	Filling
1	1343	1299	5.37	5.20	11.6	8.8
2	1390	1382	5.56	5.53	9.2	8.8
3	1282	1215	5.12	4.86	9.0	9.2
4	1389	1286	5.56	5.14	10.4	7.2
5	1411	1356	5.64	5.42	9.0	10.0
Averages -			5.45	5.23	9.84	8.80

TABLE 6 - DATA ON TEAR STRENGTH OF FABRICS

Sample 6

Test Number	Integrator Reading		Tear Strength[a] (pounds)		Load at First Break (pounds)	
	Warp	Filling	Warp	Filling	Warp	Filling
1	2419	2096	9.68	8.38	13.4	10.6
2	2049	1713	8.19	6.85	12.0	8.8
3	2226	2066	8.90	8.26	12.0	10.2
4	2078	1734	8.31	6.94	10.4	9.0
5	2682	1808	10.73	7.23	11.4	7.4
Averages -			9.16	7.53	11.84	9.20

[a]Tear Strength = $\frac{X \times L}{K}$ Where, X = integrator reading
L = full scale load - 20 lbs
K = Integrator constant - 5000

APPENDIX VIII

SAMPLE CALCULATIONS

1. **Cloth Assistance Factor:**

$$CAF = \frac{F}{nf}$$

where,
F = Fabric breaking load per inch width
n = Threads per inch
f = Yarn breaking load

Example: Sample 1 - Warp

$F = 62.4 \times 453.6$ grams
$n = 68$
$f = 351.5$ grams

$$CAF = \frac{62.4 \times 453.6}{68 \times 351.5} = 1.18$$

2. **Cloth Elongation Factor:**

$$CEF = \frac{\text{Fabric breaking elongation}}{\text{Yarn breaking elongation + crimp}}$$

Example: Sample 1 - Warp

$$CEF = \frac{39.0}{15.26 + 8.48} = 1.64$$

3. **Tear Efficiency Factor:**

$$TEF = \frac{\text{Tear strength}}{\text{Yarn strength}}$$

Example: Sample 1 - Warp

Initial tear strength = 5.18 lbs.
Average tear strength = 3.72 lbs.
Yarn strength = 351.5 gms.

$$\text{Initial } TEF = \frac{5.18 \times 453.6}{351.5} = 6.80$$

$$\text{Average } TEF = \frac{3.72 \times 453.6}{351.5} = 4.80$$

4. **Correlation Coefficient:**

$$r = \frac{n \Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{\left[n \Sigma X^2 - (\Sigma X)^2\right]\left[n \Sigma Y^2 - (\Sigma Y)^2\right]}}$$

5. **Regression Line:**

Equation of the line is $\overline{Y} = a + b\overline{X}$ where,

$$b = \frac{n \Sigma XY - (\Sigma X)(\Sigma Y)}{n \Sigma X^2 - (\Sigma X)^2}$$

$$a = \overline{Y} - b\overline{X}$$

Example: Correlation Coefficient and Regression Line relating Cloth Assistance and Cloth Elongation Factors in Warp (Data from Table VII)

Cloth Assistance Factor	Cloth Elongation Factor
X	Y
1.18	1.64
1.12	1.49
1.16	1.79
1.22	1.88
1.03	1.22
1.04	1.35

$\Sigma X = 6.75$ $\Sigma Y = 9.37$

$\Sigma X^2 = 7.6233$ $\Sigma Y = 14.9591$

$\Sigma XY = 10.6346$

$$r = \frac{(6)(10.6346) - (6.75)(9.37)}{\sqrt{\left[(16)(7.6233) - (6.75)^2\right]\left[(6)(14.9591) - (9.37)^2\right]}}$$

$$= 0.952$$

Regression Line:

$$b = \frac{(6)(10.6346) - (6.75)(9.37)}{(6)(7.6233) - (6.75)^2} = 3.16$$

$$a = \left[\frac{9.37}{6}\right] - (3.16)\left[\frac{6.75}{6}\right] = -2.00$$

Equation of the Line is $Y = 3.16X - 2.00$